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LIGHTWEIGHT VALVE

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[0001] The invention relates to a lightweight valve, in particular for internal combustion engines, according to the preamble of claim 1.

[0002] Lightweight valves of the kind referred to here are known (DE 198 04 053 A1). They are used inter alia as inlet and outlet valves for internal combustion engines and comprise a solid or hollow valve stem having only a small wall thickness, a funnel/trumpet-shaped valve cone and a valve disk for closing the valve cone, the valve disk being, for the purpose of weight reduction, provided with a recess on its flat side facing the valve cone. The recess is spaced from the peripheral surface of the valve disk, so that a plane annular surface, on which the valve cone is brought to bear with the face of its end of greater diameter, is formed at the edge. Valve cone and valve disk are welded together in their connection region. It is a disadvantage of the known lightweight valve that accurate, relative alignment of the individual parts, in particular of the valve cone in relation to the valve disk, can be brought about before the joining process only with great effort and special holding devices are necessary, which hold the valve cone and the valve disk together positionally accurately during the joining process.

[0003] It is an object of the invention to provide a lightweight valve of the kind referred to in the introduction which does not have this disadvantage.

[0004] To achieve the object, a lightweight valve with the features of claim 1 is proposed. This is characterized in that the valve cone projects with its end region of greater diameter into the recess. By virtue of this design, accurate alignment of valve cone and valve disk in relation to one another is brought about in a simple way without special devices being necessary for this. Furthermore, the engagement of the valve cone in the recess secures the valve disk against radial displacement relative to the valve cone. It is moreover advantageous that the design according to the invention of the connection region affords more weld seam formation possibilities than the known lightweight valve.

[0005] According to a first embodiment, the valve cone and the valve stem are designed as a one-piece component. In this connection, the valve cone can be produced on the valve stem by

flaring, that is by expanding the hollow stem end. According to a second embodiment of the lightweight valve, the valve cone is a separate component which is fixed at its end of smaller diameter to the valve stem or to a stem connection element provided on the valve disk and extending through the valve cone and at its end of greater diameter to the valve disk.

[0006] The diameter of the recess and the outside diameter of the valve cone at its end of greater diameter can be matched to one another in such a way that, when the valve cone is introduced into the recess, a non-positive connection is formed between these parts, by virtue of which these are interconnected non-displaceably and captively. This simplifies the handling of this subassembly formed by insertion of the valve cone into the valve disk recess during the subsequent joining process, that is when valve cone and valve disk are materially interconnected, preferably welded or soldered together. Further fastening means for connecting the valve disk and the valve stem for the purpose of pre-assembly are not necessary.

[0007] In an especially advantageous illustrative embodiment of the lightweight valve, the recess in the valve disk is designed as a centering and/or supporting seat. In this connection, the recess is preferably designed in such a way that a desired alignment of the valve cone relative to the valve disk takes place during introduction of the end region of greater diameter of the valve cone, so that it is possible to dispense with separate centering means. In this connection, the recess serves additionally or alternatively as a bearing for the valve cone.

[0008] In an advantageous illustrative embodiment, the valve disk is made from the intermetallic phase titanium aluminide (TiAl) or a TiAl alloy by casting. This valve disk has only low weight and is moreover extremely wear-resistant. According to another variant embodiment, the valve disk is made of steel, in particular tool steel, and is produced by forging. According to a third variant embodiment, the valve disk is manufactured by means of a powder metallurgy production process, in particular from a tool steel which is extremely wear-resistant.

[0009] As far as the materials which can be used for the valve stem and the valve disk are concerned, reference is made to DE 100 29 299 C2, the content of which with regard to the materials used is a subject of this description.

[0010] In an especially preferred illustrative embodiment of the lightweight valve, the valve cone is designed as a sheet metal component. High-carbon structural steel, in particular St-52, or low-alloy steel, in particular X10Cr13, for example, is used as the material. The valve cone can be produced cost-effectively by deep-drawing.

[0011] Further advantageous illustrative embodiments of the lightweight valve emerge from combinations of the features referred to in the description and in the subclaims.

[0012] The invention is explained in greater detail below with reference to the drawings, in which

[0013] fig. 1 shows a detail of a first illustrative embodiment of a lightweight valve for internal combustion engines in a perspective, cutaway illustration;

[0014] fig. 2 shows a perspective illustration of a valve cone illustrated in figure 1;

[0015] fig. 3 shows a perspective, cutaway illustration of a detail of a further illustrative embodiment of a valve disk;

[0016] fig. 4 shows a detail of a third illustrative embodiment of the lightweight valve in a perspective, cutaway illustration, and

[0017] fig. 5 shows a detail of a fourth illustrative embodiment of the lightweight valve in a sectional illustration.

[0018] Figure 1 shows part of a first illustrative embodiment of a lightweight valve 1 of multi-part design for internal combustion engines. This can be used as a thermally less loaded inlet valve or as a thermally more highly loaded outlet valve, the material of the individual parts being selected accordingly depending on the use of the lightweight valve 1.

[0019] The lightweight valve 1, which is rotationally symmetrical about its longitudinal central axis 2, comprises a valve stem 3, made of solid material here, a hollow valve cone 5 and a valve disk 7 closing the valve cone 5.

[0020] The valve stem 3, which has a circular cross section, has a longitudinal portion 9 of greater diameter which is adjoined by a longitudinal portion 11 of smaller diameter, by virtue of which an all-round annular bearing shoulder 15 is formed on the outer peripheral surface 13 of the valve stem. Alternatively, for reasons of weight reduction, the valve stem 3 can also have a hollow space. The valve stem 3 can, for example, be formed by a precision-drawn tube made of steel, for example X45, which is closed at the end which is not illustrated by means of a valve stem endpiece/foot. The valve stem 3 has a plane end face 17 at its end which can be seen in figure 1.

[0021] The valve cone 5 illustrated in figures 1 and 2 is formed by a separate sheet-metal part and has only a small wall thickness. The one-piece valve cone 5 has a basic body in the shape of a disk spring, on the end of smaller diameter of which a collar-shaped guiding and centering portion 19 is formed, which is perforated by a through-opening 21, through which the valve stem 3 extends in the joined-together state. The diameter of the through-opening 21 is the same as or greater than the outside diameter of the valve stem 3, so that either the latter extends through the through-opening 21 with play or a non-positive connection is formed between valve stem 3 and valve cone 5. When the valve cone 5 is pushed onto the valve stem 3, these parts are automatically aligned/centered in relation to one another owing to the guiding and centering portion 19.

[0022] The valve disk 7 is provided on its flat side facing the valve stem 3 with a recess 23 which serves as a bearing/seat for the valve cone 5 and into which the valve cone 5 projects with its end of greater diameter. Seen in top view, the recess 23 has a circular cross section. In this connection, the recess 23 is designed in such a way that the transition between valve disk 7 and valve cone 5 in their connection region is continuous. The hollow space of the valve cone 5 is closed by means of the valve disk 7. In the illustrative embodiment shown in figure 1, the bottom of the recess 23 is of plane design. The side wall 25 of the recess 23 extends perpendicularly to the bottom of the recess 23. The diameter of the recess 23 and the outside diameter of the valve cone 5 at its end of greater diameter are the same or approximately the same.

[0023] As can be seen from figure 1, the end face 27 of greater diameter of the valve cone 5 is located opposite the recess side wall 25, that is it is arranged completely in the recess 23. The valve cone 5 is introduced into the recess 23 with its end of greater diameter until it comes up against the bottom of the recess 23. A reproducible arrangement of the valve cone 5 in relation to the valve disk 7 is therefore brought about in a simple way.

[0024] The valve disk 7 is of disk-shaped design and has a first, cylindrical longitudinal portion 29 of constant cross section and, adjoining this, a conical second longitudinal portion 31A and also, adjoining this, a conical third longitudinal portion 31B, the cone angle of the third longitudinal portion 31B being the same as the cone angle of the valve cone 5 at its end of greater diameter, by virtue of which a continuous transition is brought about in the connection region between these parts.

[0025] In the properly joined-together state, the end face 17 of the valve stem 3 bears flat against the bottom of the recess 23, as illustrated in figure 1. The valve disk 7 is therefore supported by the valve stem 3 on its flat side facing away from the combustion chamber, so that optimum introduction of the gas forces acting on the valve disk 7 into the valve stem 3 can be ensured, without inadmissibly great deformations of the valve disk 7 and of the valve cone 5 arising in this connection. Owing to the design according to the invention of the lightweight valve 1, it is possible to ensure that the valve cone 5 is virtually force-free during operation of the lightweight valve 1, that is that only very small forces – if any – are introduced into the valve cone 5 via the valve disk 7. The valve cone 5 can therefore be designed with very thin walls, which is advantageous in manufacture of the same and moreover contributes to reducing the weight of the lightweight valve.

[0026] The valve disk 7 and the valve stem 3 are interconnected inseparably by means of a material connection. This can be effected by means of, for example, friction welding, beam welding, fusion welding or capacitor discharge welding. Additionally or alternatively, the valve stem 3 can be welded together with the valve disk 7 on its end face 17.

[0027] Before or after the material connection of valve stem 3 and valve disk 7, the valve cone 5 is pushed onto the valve stem 3, in particular until its end region of greater diameter engages in

the recess 23. The valve cone 5 is welded together with the valve stem 3 in the region of the guiding and centering portion 9 and with the valve disk 7 in the connection region lying in the region of the recess 23, in particular preferably by means of a friction, beam or fusion welding procedure.

[0028] It remains to state that the valve cone 5 has a reduced wall thickness in the region of its guiding and centering portion 9, so that only a narrow bearing shoulder 15 on the valve stem 3 is sufficient in order to bring about a continuous transition between valve cone and valve stem.

[0029] In another illustrative embodiment not shown in the figures, the valve stem 3 has a constant cross section in the connection region of the valve cone 5, that is on its end region of smaller diameter, by virtue of which an all-round edge step is formed by the end face of the valve cone 5, which step has only a small width, however, owing to the reduced wall thickness of the valve cone 5. The influence on the combustion gas guidance in the region of the outer contour of the valve cone 5 is therefore only slight.

[0030] The lightweight valve 1 described above with reference to figures 1 and 2 is characterized in particular in that its individual parts can be interconnected or prefixed in a simple way by fitting together and that in this connection automatic alignment/centering of the individual parts takes place owing to their constructional design.

[0031] The gas forces acting on the valve disk 7 during operation of the lightweight valve 1 are advantageously supported via the valve stem 3 bearing centrally against the valve disk 7. In this connection, it can be ensured that the gas forces acting on the valve disk 7 cannot, or can only to a harmless extent, be introduced into the very thin-walled valve cone 5. Deformation of the valve cone 5 can therefore reliably be excluded.

[0032] Figure 3 shows a detail of a second illustrative embodiment of the valve disk 7. The same parts are provided with the same reference numbers, so that in this respect reference is made to the description for figures 1 and 2. In this illustrative embodiment, three reinforcing ribs 33 molded into the valve disk 7 are provided in the recess 23. In the illustration according to figure 3, only the reinforcing ribs 33A and 33B can be seen. Seen in a top view of that flat side of the

valve disk 7 facing the valve stem 3, the reinforcing ribs 33 extend radially in relation to the longitudinal central axis 2 of the lightweight valve 1 and are arranged at a spacing of 120° from one another. The length of the reinforcing ribs 33 originating from the edge region of the recess 23 in the direction of the valve disk center corresponds approximately to half the radius of the valve disk 7. As can be seen from figure 3, the reinforcing ribs 33 are in this illustrative embodiment designed as rectilinear strips of which the height increases in the direction of the valve disk center and the width decreases in the direction of the valve disk center.

[0033] The reinforcing ribs 33 are designed to complement the inner wall of the valve cone 5, so that the latter, in the joined-together state of the lightweight valve 1, rests flat with its inner wall on the upper narrow side 35 of the reinforcing ribs 33 and is consequently supported by these. The valve cone 5 and the reinforcing ribs 33 can be welded or soldered together on their bearing contact region.

[0034] As can be seen from figure 3, the recess 23 is in its edge region provided with an all-round edge step 37 which serves for supporting or as a bearing shoulder for the valve cone 5 and is designed in such a way that the valve cone 5 bears on its inner side against the bottom of the edge step 37. Such an edge step 37 is also provided in the illustrative embodiment of the lightweight valve 1 shown in figure 1.

[0035] The valve disk 7 with the reinforcing ribs 33 designed in one piece thereon can be manufactured cost-effectively by forging owing to its simple geometry.

[0036] It remains to state that the valve stem 3 and the valve disk 7 can be made from the same material or from different materials. The connection between valve disk 7 and valve stem 3 can in particular be effected by means of friction welding, beam welding, fusion welding or capacitor discharge welding in all the illustrative embodiments of the lightweight valve 1 described with reference to figures 1 to 3 as well. Connecting the valve disk 7 and the extremely thin-walled valve cone 5 is preferably effected by means of beam, fusion or laser welding.

[0037] In summary, it remains to state that the lightweight valve 1 according to the invention is characterized in particular in that, in addition to its only small weight, it has only a few

individual components, which can be interconnected with a few simple joining operations, so that it can be produced cost-effectively overall.

[0038] Figure 4 shows a detail of a further illustrative embodiment of the lightweight valve 1. The same parts are provided with the same reference numbers, so that in this respect reference is made to the description for the preceding figures. Here, the valve stem 3 is of tubular design and therefore has a stem hollow space 39, which is closed by means of a valve stem endpiece/foot at the end of the lightweight valve 1 which is not illustrated. The valve cone 7 is formed by expanding the diameter of the valve stem end. The expansion of the valve stem end and the special shape of the valve cone 5 result in a conical transition from the stem hollow space 39 to the valve cone 7.

[0039] A supporting dome 41 which projects beyond the flat side of the valve disk 7 and has in its center a recess 43 extending in alignment with the stem hollow space 39 is formed on in the center of the valve disk 7. The supporting dome 41 has an annular cross section and bears against the valve cone 5 in the region of its end face 45.

[0040] In the illustrative embodiment shown in figure 4, the supporting dome 41 is connected materially to the valve cone 5 by means of capacitor discharge welding. In this regard, the end face 45 is deformed in such a way by partial fusion and pressing of the valve disk against the valve cone that the bearing contact surface 47 of the supporting dome 41 is formed to complement the opposite inner wall region of the valve cone. The valve cone 5 can also be connected to the valve disk 7 at its end of greater diameter in the region of the recess 23 by means of capacitor discharge welding, so that fixing can take place in both regions mentioned in one operation. Other material connection variants are of course also possible.

[0041] The bearing contact surface 47 between the supporting dome 41 and the valve cone 5 can be of all-round design, so that the recess 23 in the valve disk 7 forms a closed-off annular chamber, the walls of which are formed by the valve disk, the valve cone and the supporting dome. It may be advantageous to avoid closed-off spaces/chambers, which can be brought about in the illustrative embodiment shown in figure 4 by virtue of, for example, the bearing contact surface 47 being interrupted by slits, so that at least one medium connection exists between the

recesses 23 and 43 in the welded state of valve disk 7, or supporting dome 41, and valve cone 5 as well. This makes it possible to exclude local pressure differences in the lightweight valve 1. The medium connection can additionally or alternatively also be formed by one or more openings/bores extending transversely to the longitudinal extent of the supporting dome 41.

[0042] The hollow lightweight valve 1, which is closed sealingly at its one end by means of the valve endpiece and at its other end by means of the valve disk 7, can be filled with a cooling medium, for example sodium. In this connection, both the stem hollow space 39 and the recess 43 in the supporting dome 41 are filled with the cooling medium, so that both valve stem and valve disk and also valve cone are cooled. Provided a medium connection as described above is provided between the recesses 43 and 23, the cooling medium also passes into the chamber formed by the recess 23 and can, with an appropriate design of the medium connection, also circulate there, which contributes to improving the heat dissipation from the valve disk.

[0043] Figure 5 shows a detail of a further illustrative embodiment of the lightweight valve 1. Parts which have already been described with reference to the preceding figures are provided with the same reference numbers, so that in this respect reference is made to figures 1 to 4. The valve disk 7 has on its flat side having the recess 23 a stem connection element 49 which is designed in one piece with the valve disk 7 and is located in its center. The stem connection element 49 is at its free end connected to the valve stem 3, which is effected by means of friction welding in the illustrative embodiment shown in figure 5. The all-round bulging friction weld seam 51 is removed by machining in a subsequent operation. In this illustrative embodiment, the length of the stem connection element 49 is selected in such a way that, when the lightweight valve 1 has been assembled, the connection region between stem connection element 49 and valve stem 3 is arranged outside the valve cone hollow space. This design affords both the possibility of first connecting the valve cone 5 to the valve disk 7 and the stem connection element 49 and only then connecting the valve stem 3 to the valve disk 7 and also the alternative method variant of connecting the valve stem 3 to the stem connection element 49 in a first step and then connecting the valve cone 5 to the valve disk 7 and the stem connection element 49 in a second step.

[0044] The stem connection element 49 has in its region of connection to the valve stem 3 the same outside diameter and the same shape as the valve stem 3, by virtue of which a continuous transition can be brought about.

[0045] Means for partial internal support of the thin-walled valve cone 5 are provided on the stem connection element 49, which means are formed in this illustrative embodiment by a thickening 53 formed on the stem connection element 49 which - seen in the direction of the longitudinal central axis 2 of the lightweight valve 1 - is located at an axial distance from the bottom of the recess 23, or of that flat side of the valve disk 7 facing the valve cone 5. The thickening 53 has a conical supporting surface 55 of all-round design in the illustrative embodiment according to figure 5, which is in bearing contact with an inner wall region of the valve cone 5, by virtue of which the valve cone 5 is supported. The contour of the supporting surface 55 is designed to complement this valve cone inner wall region, by virtue of which contact over the entire surface can be ensured.

[0046] The distance of the thickening 53 from the valve disk 7 and its design are such that the valve cone 5 pushed onto the stem connection element 49 is both centered in relation to the valve disk 7 and held at such a distance from the valve disk 7 that the valve cone 5 projects into the recess 23 with its end of greater diameter in the desired way.

[0047] The valve cone 5 differs from that described with reference to figures 1 and 2 in that it has a simpler shape which is more cost-effective to produce, namely that of a disk spring.

[0048] It remains to state that the valve cone 5 is in each case supported and centered by means of the thickening 53 at its end of smaller diameter and by means of the recess 23 at its end of greater diameter.

[0049] In the illustrative embodiment according to figure 5, it is to be emphasized as especially advantageous that the valve cone 5 has a diameter d at its end of smaller diameter which is markedly greater than the outside diameter of the valve stem 3, so that the valve cone 5 can easily be slipped over the valve stem 3 even with the friction weld seam 51 present. Owing to the disk form of the valve cone 5, the valve stem 3 does not have to have a step either, that is a

diameter jump, in order to bring about a continuous transition between valve cone 5 and stem connection element 49, as can be seen from figure 5. The valve cone 5 bears flush against the thickening 53 in the transition region.

[0050] In an illustrative embodiment not shown in the figures, the thickening 53 is formed on the valve stem 3. The connection location between valve stem 3 and stem connection element 49 is then located inside the valve cone hollow space. Alternatively, the stem connection element 49 can be dispensed with and the valve stem 3 having the thickening 53 – as in the illustrative embodiment described with reference to figure 1 – can be directly in contact and welded together with the valve disk 7.

[0051] In the illustrative embodiment according to figure 5, the stem connection element 49 has a blind hole opening 57 which extends in alignment with the stem hollow space 39 and as far as the valve disk 7. In order for it to be possible to ensure uniform pressure conditions in the lightweight valve 1, slit-shaped openings 57 arranged at 90° from one another, which connect the annular valve cone hollow space delimited by the valve cone, the valve disk and the stem connection element 49 to the blind hole opening 57, are provided in the stem connection element 49. The lightweight valve 1 can be filled with a cooling medium which can spread throughout the lightweight valve 1 owing to the openings 59, which contributes to improved cooling of the valve.

[0052] The illustrative embodiment described with reference to figure 5 can be filled with the cooling medium especially easily by the valve stem, the valve cone and the valve disk first being interconnected and the cooling medium then being introduced via the open, free end of the hollow valve stem. The free valve stem end is then closed, for example by the stem endpiece being forged on.

[0053] Owing to its construction described above, the illustrative embodiment described with reference to figure 5 is characterized by easy machinability of the seat/bearing surfaces (supporting surface 55 and recess 23 or edge step 37) for the valve cone 5.